CHERT DEPOSITS IN ECUADOR, SOUTH AMERICA

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CHERT DEPOSITS IN ECUADOR, SOUTH AMERICA

by

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INTRODUCTION

The following notes have been recorded with the idea of showing that a field relationship exists between true chert veins or aggregations, and certain igneous intrusions. Beyond the fact that the cherts have been formed probably as the result of some hydrothermal agency, usually associated with, and occasionally the result of, volcanic episodes, it is not possible to enter more fully into the geological origin of this form of silica. Microscopic fossils have been observed and recorded from the cherts of Santa Elena[1], but the presence of these organisms may be accounted for by the fact that certain Radiolaria are able to exist in waters of a fairly high temperature, it is also possible that these fossils may have been abstracted from the vein walls of the country rock during the secondary process of infilling by crypto-crystalline silica.

The sketch-maps appended herewith by no means indicate the whole of the dyke and chert occurrences which are found in this part of the country; many more undoubtedly exist, but only those which have actually been mapped by the writher are shown.

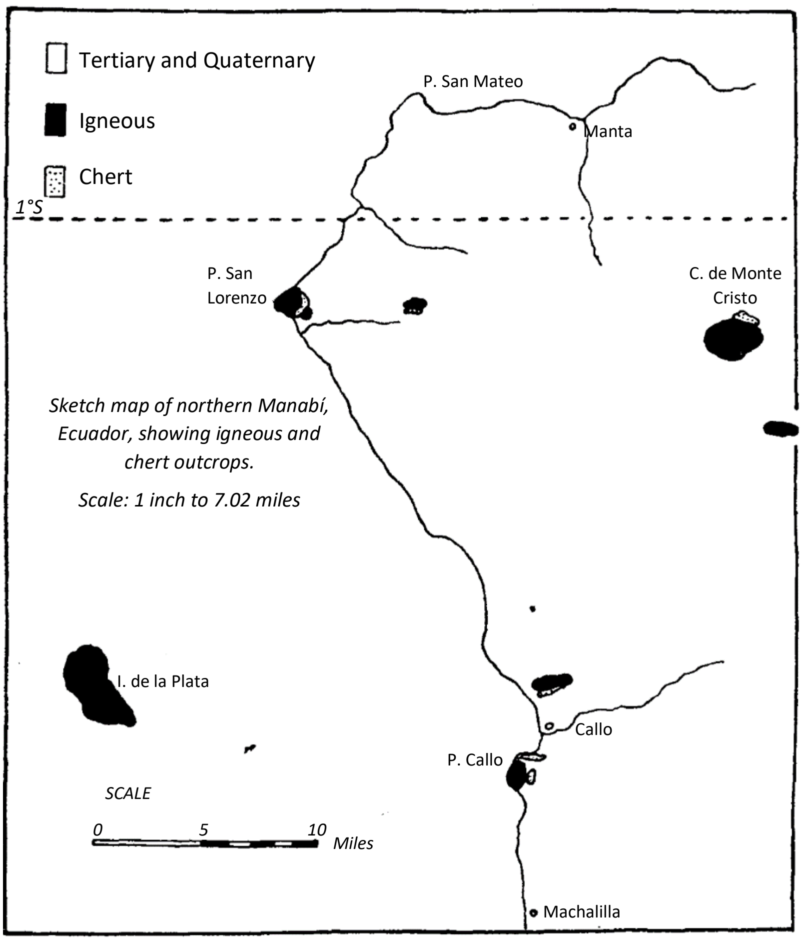

FIG. 1 – Sketch-map of the northern part of the province of Manabí, showing principal intrusions and chert outcrops. Scale: 1 inch to 7.02 miles

[1] Joseph Sinclair and Charles P. Berkey, *Cherts and Igneous Rocks of the Santa Elena Oilfield, Ecuador*, New York

GEOGRAPHICAL DISTRIBUTION

As referred to above, the respective outcrops of chert and igneous rocks indicated in Figs. 1 and 2 do not limit the entire distribution of these phenomena in southern Ecuador. Other occurrences of a similar nature are found, especially in the province of Manabí to the north, and it is known that an easterly extension of the map (Fig. 2) would reveal further outcrops of these rock types. The areal geology of this district includes Recent, Quaternary, and Tertiary deposits, whilst post-Tertiary intrusions are very common, the most important being known as the Cerro de Monte Cristo. The latter conspicuous hill forms but one of a series of similar intrusions, the most westerly on the mainland occurring at Punta San Lorenzo. Masses of chert are invariably found in close association with this series of dyke rocks.

Further to the south also a group of intrusions can be examined in the neighborhood of Callo and inland for about ten miles. The most westerly outcrop of the latter is known as Isla de la Plata, an island consisting entirely of a basaltic type of volcanic rock, superimposed by thin Tablazo deposits of Quaternary age[2].

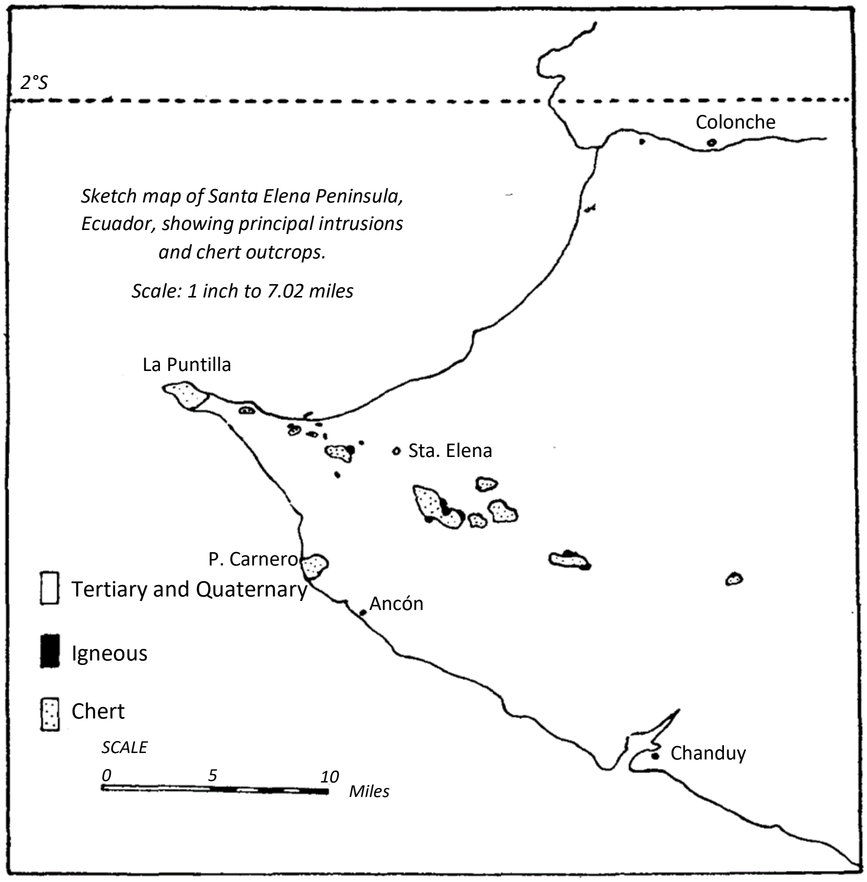

FIG. 2 – Sketch-map of Santa Elena peninsula, Ecuador, showing principal intrusions and chert outcrops. Scale: 1 inch to 7.02 miles

[2] G. Sheppard, "Geological Observations on Isla de la Plata, Ecuador, South America": *Amer. Jour. Sci.*, 5th ser., vol. xiii, 1927

The headland known as Punta Callo is actually a dyke formation which has intruded the Tertiary shales and sandstones (Pl. XIII). A striking series of metamorphosed shales with attendant cherts can be observed also from this point southwards in the direction of Machalilla. The sketch-map (Fig. 2) represents what is known as the peninsula of Santa Elena, being the most westerly point of Ecuador and also forming the northern arm of the Gulf of Guayaquil.

It will be observed that a distinct line of intrusions extends almost from the point, La Puntilla, in a south-easterly direction for many miles. La Puntilla consists, in the main, of highly silicified shales or opaque white chert, with occasional small inliers of volcanic rock. There is no doubt that the existence of this long peninsula of Santa Elena, jutting far out into the Pacific at the present time, is due to the fact that the Tertiary terrain has been reinforced by this backbone of igneous and chert masses and thus has resisted, to a certain extent, the forces of marine erosion which are very intensive along this section of the coast.

Fig. 4 represents a map of a portion of the principal chert-igneous complexes on a larger scale, this occurring to the south-east of the town of Santa Elena. Although this area is disturbed considerably, it will be noticed that the cherts and dykes are intimately associated in the field, and undoubtedly have some connection the one with the other.

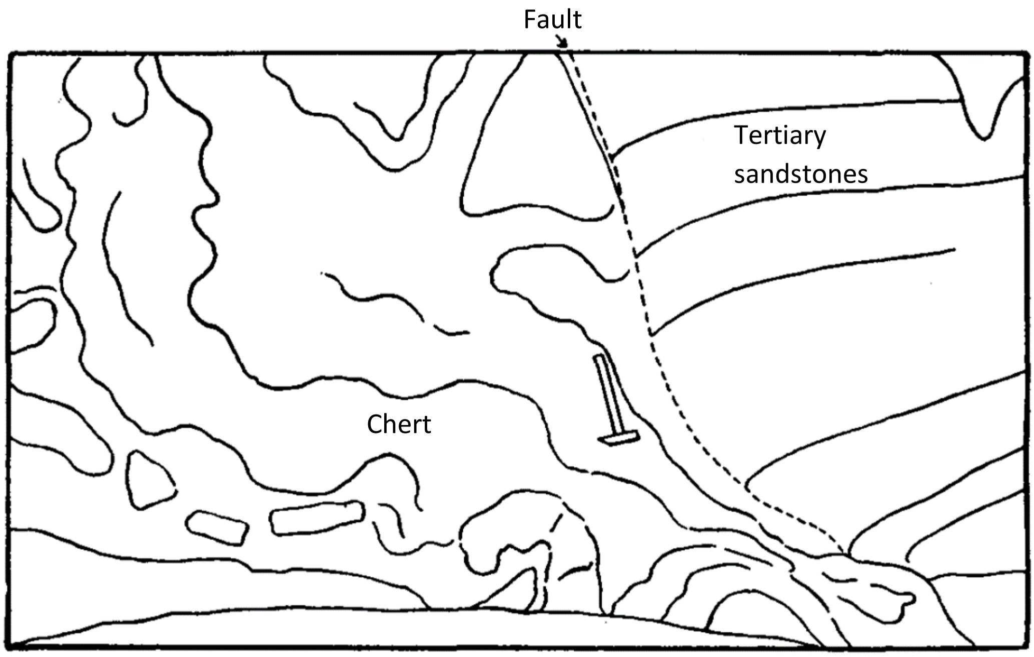

FIG. 3 – Crushed zone with chert. See PLATE XIII (c)

a)

b)

c)

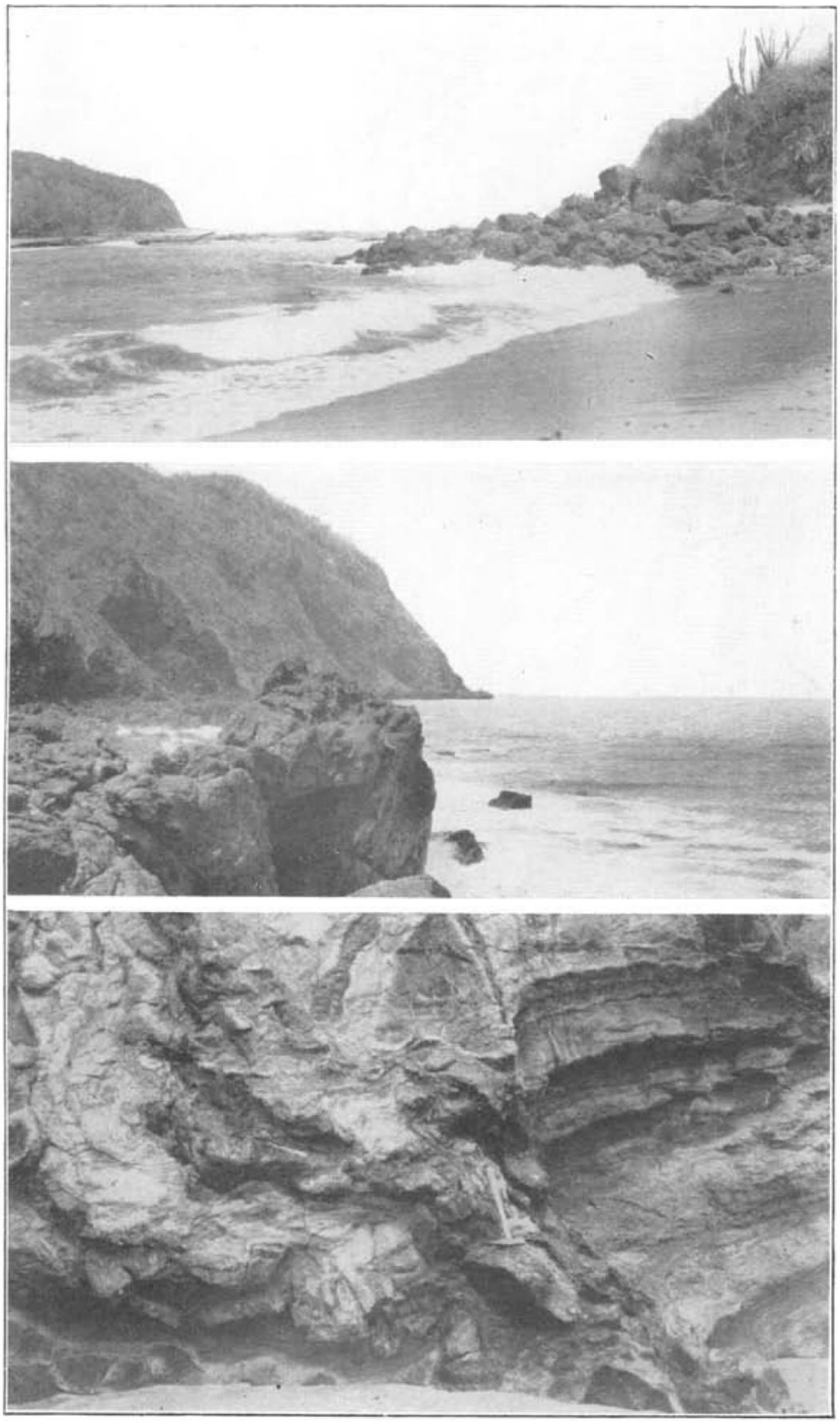

PLATE XIII (a). – Punta Callo, Ecuador.

PLATE XIII (b). – Punta Callo, Ecuador, showing nature of dyke. Masses of chert are found in close proximity.

PLATE XIII (c). – Crushed and faulted zone in Tertiary Formations near a volcanic intrusion (Punta Callo, Ecuador).

MODE OF OCCURRENCE

The greater part of the coast-belt or littoral of southern Ecuador consists principally of Quaternary and Tertiary deposits, the latter, for the most part, being made up entirely of sandstones, shales, and occasional conglomerates. These formations, however, have been altered locally near the presence of volcanic dykes. The Quaternary deposits are known as tablazos and these consist, in effect, of raised beaches, or sea-floors, which extend over a large area. The tablazos always cover the Tertiary formations unconformably and in no case has a dyke been observed to penetrate the tablazo. The dykes, therefore, are of post Tertiary and pre-Quaternary age.

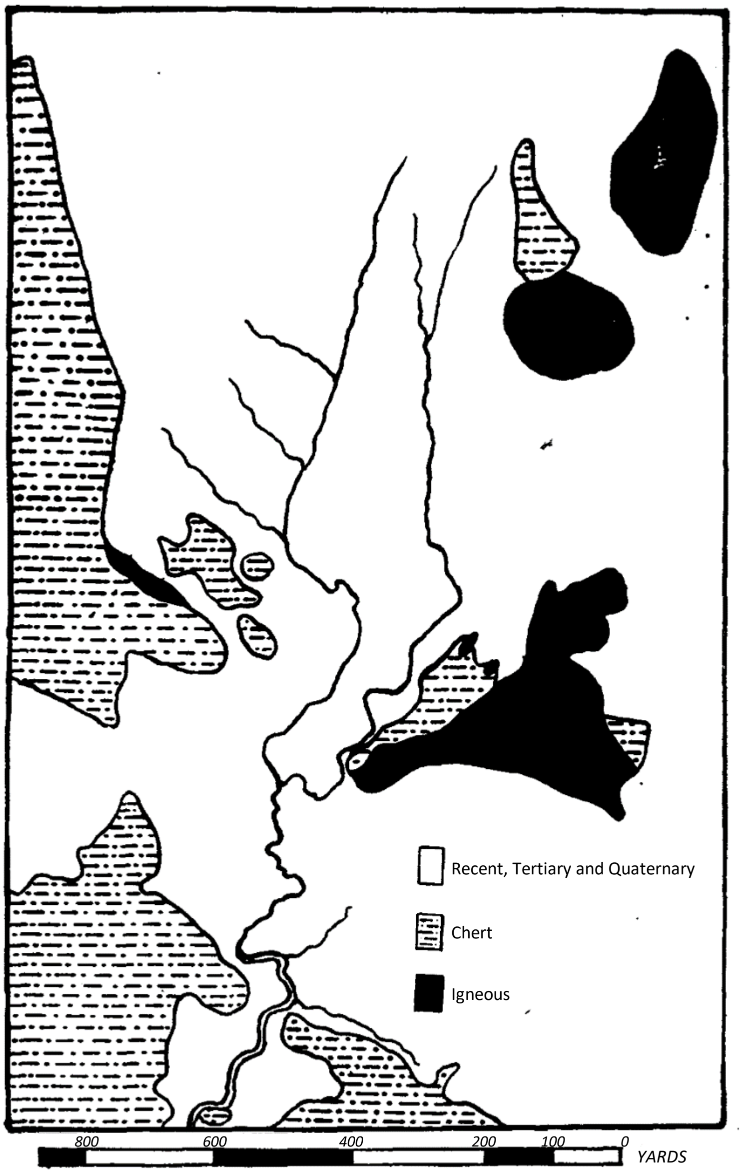

FIG. 4 – Sketch-map of chert-igneous complex to the south-east of Santa Elena, Ecuador. (After Murray[3]). Scale 6.3 inches to 1 mile

[3] Murray, A. J. R., 1925. A report on the southern property of the AEOL and adjacent territory, AEOL. ?

In the region under consideration the cherts are found in irregularly disposed masses among the shales and sandstones wherever the latter deposits have been changed, in a lithological sense, by the metamorphism induced by the post-Tertiary intrusions. The cherts are apparently true vein-deposits of secondary origin and vary in size from microscopic “stringers” to enormous masses measuring several feet across.

Observations in the field have established the corollary that wherever cherts are found in association with the Tertiary formations of this region, volcanic dykes and zones of metamorphism can be expected. In many cases the cherts seem to consist entirely of translucent, colourless silica, but other occurrences present a variety of types, each of which has been determined by the local conditions under which the segregation of silica took place, and by the chemical nature of the country rock. In his latter respect it is of interest to note the composition of the typical shales of this region and to cite the following analysis[4]:

Table 1. UPPER EOCENE SHALE, QUEBRADA ENGABAO

	%
Moisture	9.24
Silica	78.19
Iron oxide and aluminium oxide	10.74
Calcium carbonate	1.59
Magnesium carbonate	0.24

From the above it will be seen that these shales have a high silica content, it being probable that, in the first instance, they originated from the denudation of an extensive Cretaceous land-mass to the north and east of the present coast.

A series of indurated sediments, therefore, consisting of argillites and porcellanites, has resulted near an igneous dyke where the latter has intruded the Tertiary formations. These altered types are invariably characterized by the presence of innumerable shrinkage cracks which have been caused apparently by the rapid cooling of the contact zone shortly after the initial intrusion. As will be referred to below, these minute planes or joints were later infiltrated by secondary silica, this being due, in all probability, to the influences of hydrothermal action.

An opaque white chert collected from a dyke-contact near San Vicente yielded the following analysis:

Table 2.

	%
Moisture	1.27
Silica	80.07
Iron oxide and aluminium oxide	1.59
Calcium carbonate	16.81
Calcium sulphate	0.26

(Cf. analysis, above.)

- **Chert aggregation conditions**

The massive forms of amorphous chert have a more complicated history, and from the field evidence it can be suggested only that they have been aggregated under one or more of the following conditions:

1. In a crush-belt or shatter-zone in the vicinity of an intrusion (Fig. 3).

2. Along a slickensided joint, and in the bedding planes contiguous to the displacement.

3. In a solution cavity formed in the metamorphosed sediments.

[4] Analysis by L.F. Whitfield

In the first case the chert has usually a brecciated appearance, the angular fragments of opaque silica having been enclosed more or less ophitically in a translucent matrix of the same material. In this type the chert is vari-coloured from brown to yellow, and the matrix itself has been permeated by small veins or inflorescences of coloured silica.

In almost every example the dominant colour has been determined primarily by the alteration of a natural iron compound indigenous to the country rock. In connection with this type of siliceous aggregation the genetic history can be traced in at least three stages. Owing to the initial nature of the crush belt in which the chert occurs it is obvious that the joint, or plane of dislocation will contain angular fragments of either indurated shale or the altered sandstone elements which are found occasionally intercalating the shale deposits. The latter always possess a fairly high iron content, either in the form of an oxide or a carbonate.

The three principal stages therefore, can be outlined briefly as follows:

(a) A crush-belt of angular shale or sandstone in the dislocated zone near the intrusion. This breccia would no doubt be in a state of compression owing to the rock pressure, but no infiltration or hydrothermal silicification would take place until after a considerable interval of time.

(b) A gradual deposition of silica formed around the constituent fragments of the above breccia would then follow, with a separation of the ferrous compounds. At the same time a partial replacement of the breccia by amorphous silica would be initiated, the various colours resulting from the degradation of the iron compounds present in the brecciated material.

(c) The final and complete replacement by silica then follows, which would result in a homogeneous aggregation of chert enclosing the angular fragments of the primary crush-breccia.

In example 2 the chert has a slightly banded aspect and also appears to be traversed by a series of shrinkage planes or minute faults. In this case it is possible that the whole siliceous mass has been fractured subsequent to consolidation by the action of a later rock movement which operated along the original slickensided zone. Normally, this type of chert is fairly homogeneous and has been formed probably as a true example of siliceous infiltration with little admixture of coloration such as has been described under 1.

Finally, in 3, the chert has been formed in a rock cavity occurring in the indurated formations, and has been aggregated through a process of leaching comparable to the growth of an agate in the vesicle of a decomposed volcanic lava. The massive forms of chert can be assigned probably to the above class, their irregular and fantastic shapes having been governed by the contour of the cavity itself.

- **Chert varieties**

It is of interest to note that the massive cherts present the greatest variation in colour, and although the range is fairly extensive, from white, reds and browns, to black it has been observed that the red varieties are usually associated with altered sandstones, or shales containing an appreciable sandstone element, whilst the greyish-white forms are found only in the shales. Summarizing, therefore, the varieties of chert found in this region include the following:

(1) Black Vitreous Chert. – this is a compact, jet-black semitranslucent type which has the general appearance of an obsidian. It rarely occurs massive but is characterized by an in-veining habit, being intercalated amongst other grey or white chert aggregations. Not infrequently the white cherts, probably derived from the silicified shales, are minutely veined with the black variety, and the latter thus forms a striking contrast to the matrix.

The black chert is also found in irregular groupings which are more or less lenticular in habit, and these appear to indicate a certain parallelism in the country rock. It is possible that the strain cavities in the parent rock, due to subsequent differential movement, have been filled in secondarily by the translucent variety of silica. The latter, however, is peculiarly hard and hence weathers out conspicuously from the surface of the lighter-coloured cherts. The dark colour of the rock is due probably to included carbonaceous material after the manner of true black flint, and it may also contain magnetite in a comminuted or ultra-microscopic form. The exposed surfaces of the black chert weather to white or grey as in normal lint, and it is possible that this phenomenon is due to its porosity and to the partial solution induced by the action of capillary water.

(2) ***White Opaque Chert***. – The white cherts are probably the most widely distributed forms in the whole area under consideration. The field evidence appears to confirm the view that the white cherts represent an advanced stage of a silicified shale: they are also found commonly in association with igneous outcrops. The fact that certain microscopic organisms in a fossil state have been recognized in this and allied forms of chert is not surprising, as the unaltered Tertiary formations contain Radiolaria and Foraminifera in considerable profusion. The chert has the normal hardness of ordinary silica, and breaks with a conchoidal fracture. It is fairly brittle, however, this phenomenon being probably explained by the fact that the matrix is usually intersected by minute cracks or joints.

This variety of chert is found in large masses which weather out as hills or conspicuous outcrops in the general topography of the country. Whilst signs of stratification can be detected usually in connection with this type of formation, the individual beds are disturbed and shattered, a condition which has no doubt been occasioned by the proximity of volcanic dykes. In the San Vicente region, to the east of Santa Elena, dykes can be seen in actual contact with the cherts, whilst at La Puntilla where large outcrops of this variety are found, small dykes or isolated inliers of igneous rock can be seen involved in the siliceous groundmass itself. These latter occurrences are peculiar, and it is difficult to explain why these blocks of igneous material should be so enclosed in the irregularly disposed masses of white chert. It is obvious, however, that they follow certain trends or planes in the chert and it is possible that they represent a selvedge or fringe of a more deep-seated dyke which has been forced upwards along a fracture plane during the final consolidation of the intrusion.

As referred to above **(1)**, this variety of chert is frequently veined by black, flinty silica, and the latter also appears to occupy the strain-cavities which are found in the parent white chert.

Large spheroidal masses of banded chert occur commonly in association with the white and grey varieties. These can be designated “Augen Cherts”, and will be described below.

(3) Augen Chert. – In many localities the Augen Cherts are found in association with the white variety. In rare cases they are slightly coloured, but they are distributed more commonly amongst the grey or white types. The “augen” vary in size from a few inches to two or three feet in diameter and they are generally ellipsoidal or egg-shaped. Apparently, they are non-nuclear but present concentric bands of silica (black or translucent) alternating with the white chert. In this respect they are very similar to the banded flint which is found in the Cretaceous Formations of England and other countries.

From the hand specimen it seems possible that the banded varieties of chert had an origin in the white opaque type, and appear to be a secondary form resulting from a separation of the clear silica in defined bands. On the other hand, the augen are invariably traversed by cracks or veins in an irregular manner, and these are always filled with translucent or clear silica.

In certain specimens collected from the opaque chert incipient banding can also be observed. This always appears in the matrix as originating from a transverse vein. It is possible, however, that the latter has been derived in a secondary manner from the siliceous material constituting the concentric banding in the groundmass of the rock.

The respective laminae of the augen flake off separately upon exposure to the atmosphere, this being due possibly to the relative hardnesses of the two forms of silica. It has been observed also that the white opaque chert is distinctly porous when compared with the translucent variety. No explanation can be offered to account satisfactorily for the banded habit of these cherts. It can be suggested tentatively, however, that has the clear silica forms the concentric bands in the augen, apparently ramifying from the transverse veining, there is probably some connection between the two siliceous forms (Fig. 5). It seems improbable that the augen cherts have been formed after the manner of an agate. The respective bands do not suggest phases of siliceous deposition, but rather they represent successive infiltrations probably associated with internal leaching within the chert mass itself.

(4) Brecciated Cherts. – As referred to previously, the brecciated cherts are usually found in association with altered sedimentaries which have been deformed along a fault plane, or the plane of an overthrust. Wherever intense tectonic movement has affected the original disposition of the Tertiary beds, local crush zones have been formed, and very often these have been filled with typical crush-breccias derived from the country rock. In addition to this type a further example can be quoted where an open joint in the stratified rocks has been filled in by weathered angular fragments fallen from the rock walls of the cavity. With the exception that the latter material is more loosely consolidated, the two types of breccia are difficult to differentiate, without reference to the disposition of the contiguous strata. As a rule, the brecciated cherts are vari-coloured and it has been observed that the highly coloured forms, namely the reddish varieties, are nearly always present where a dyke has invaded an arenaceous formation, whilst the grey, black and light-coloured varieties indicate the alteration of shales or similar strata of argillaceous derivation.

The precise mineralogical and chemical changes which have taken place in producing the phenomena displayed by these cherts and silicified shales have not yet been worked out for this area, but as these types of rock are often found as dyke-contacts they must represent a series of secondary formations induced possibly by the addition of the silica element from the dyke (though the dykes are basic in composition) or by the degradation of the original shales and sandstones as a consequence of thermal metamorphism. Several low hills consisting of whitish chert are found in the San Vicente region and in two instances, at least, a coarse andesitic type of igneous rock can be seen in contact with the altered sedimentaries. In every case, also, where the indurated shales and cherts occur, the strata are shattered and distorted very considerably, and it is possible that the minor structural features of the geology of this region are primarily due to the presence of this series of intrusions. It is assumed, therefore, that the opaque white cherts are silicified shales caused by the alteration of the original Tertiary formations.

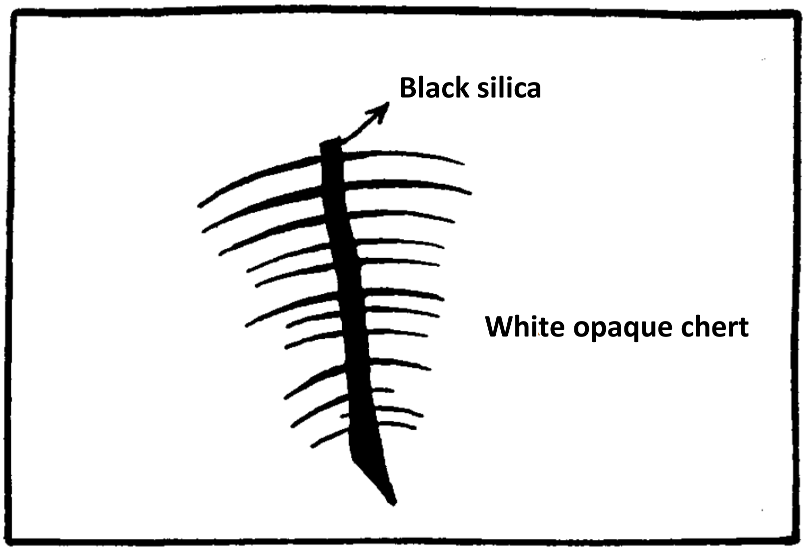

FIG. 5 Black silica and white opaque chert

The true sandstones, however, when metamorphosed, present equally striking features. They are usually characterized by a distinctive reddish colour, and they are also indurated and silicified to such an extent that they approach a true quartzite in appearance and constitution. In the majority of cases the bedding planes of the sandstone are still preserved, but the whole body of the rock has been changed into a hard, siliceous material, which is very flinty and tenacious in texture.

CONCLUSIONS

(1) The cherts occurring in the region under consideration have a distinct connection with the presence of igneous intrusions.

(2) Two major classes of chert can be recognized:

(a) Primary. Vein material infilling natural cavities and planes of structural displacement. This class of chert has been deposited from solution as a direct result of proximity to igneous intrusions.

(b) Secondary. Tertiary shales which have become completely silicified – a probable result of contact metamorphism and injection.

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Updated maps for Figures 1 and 2